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We claim:

1. A method for producing semiconductor laser components, which comprises:

providing a cooling element having an electrically insulating carrier that is formed as a plate having a main surface which is covered by a metal coating;

structuring the metal coating to form a plurality of chip mounting areas;

fitting a plurality of semiconductor laser chips on the plurality of the chip mounting areas; and

subdividing the cooling element into a plurality of semiconductor laser components that each include at least one of the plurality of the semiconductor laser chips and a part of the cooling element.

2. The method according to claim 1, which comprises providing the carrier with a ceramic material.

3. The method according to claim 1, which comprises:

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providing the carrier with a plurality of layers in which one of the plurality of the layers is adjacent the main surface; and

providing at least the one of the plurality of the layers that is adjacent to the main surface as an electrically insulating layer.

4. The method according to claim 1, which comprises constructing the carrier with a material selected from the group consisting of AlN and BN.

5. The method according to claim 1, which comprises configuring the plurality of the chip mounting areas in a matrix form.

6. The method according to claim 1, which comprises performing the structuring step by etching the metal coating.

7. The method according to claim 1, which comprises providing at least some of the plurality of the chip mounting areas with a surface treatment.

8. The method according to claim 1, which comprises providing the metal coating with a plurality of layers.

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9. The method according to claim 1, which comprises providing the metal coating with copper.

10. The method according to claim 1, which comprises:

before performing the fitting step, providing the plurality of the chip mounting areas with a plurality of connecting pads; and

performing the fitting step by configuring the plurality of the semiconductor laser chips on the plurality of the connecting pads.

11. The method according to claim 10, which comprises providing the plurality of the connecting pads with AuSn.

12. The method according to claim 11, which comprises before performing the fitting step, covering the plurality of the connecting pads with an electrically conductive adhesive material.

13. The method according to claim 10, which comprises before performing the fitting step, covering the plurality of the connecting pads with an electrically conductive adhesive material.

14. The method according to claim 13, which comprises providing the electrically conductive adhesive material as a solder coating.

15. The method according to claim 1, which comprises performing the fitting step by soldering on the plurality of the semiconductor laser chips.

16. The method according to claim 1, which comprises performing the fitting step by soldering on the plurality of the semiconductor laser chips using a hard solder.

17. The method according to claim 1, which comprises forming interconnect structures on the main surface between individual ones of the plurality of the chip mounting areas.

18. The method according to claim 1, which comprises:

opposite the main surface, forming a plurality of metal surfaces on the carrier; and

associating the plurality of the metal surfaces with the plurality of the chip mounting areas.

19. The method according to claim 1, which comprises providing the cooling element with a thermal coefficient of

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expansion that is matched to a thermal coefficient of expansion of the plurality of the semiconductor laser chips.

20. The method according to claim 1, which comprises before the structuring step, forming weak points between the plurality of the chip mounting areas.

21. The method according to claim 20, which comprises forming the weak points by performing a process selected from the group consisting of scratching, milling, and laser ablation.

22. The method according to claim 1, which comprises providing the plurality of the semiconductor chips as GaAs laser diodes.

23. The method according to claim 1, which comprises providing the plurality of the semiconductor chips as high-power GaAs laser diodes.

24. The method according to claim 1, which comprises before performing the subdividing step, fitting a plurality of optical elements, which are associated with the plurality of the semiconductor laser chips, to the cooling element.

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25. The method according to claim 1, which comprises in between the fitting step and the subdividing step, testing the plurality of the semiconductor laser chips.

26. The method according to claim 25, which comprises performing the testing step by including a test of an optical functionality of the plurality of the semiconductor laser chips.

27. The method according to claim 25, which comprises performing the testing step by including a burn-in cycle of the plurality of the semiconductor laser chips.

28. The method according to claim 25, which comprises performing the testing step by including a quality selection of the plurality of the semiconductor laser chips.

29. The method according to claim 25, which comprises performing the testing step by simultaneously testing at least some of the plurality of the semiconductor laser chips.

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the major surface having the AlGaInN semiconductor layer **20** of the former toward the latter and positioning the p-side electrode **21**, n-side electrode **22** and dummy n-side electrode **23** of the former substrate in alignment with the solder layers **34**, **36** and **37** of the Si substrate **31**, and they are bonded together. In this process, since the difference in height of the Si solder layers **36**, **38** from the Sn solder layer **34** is equal to the difference in height of the p-side electrode **21** from the n-side electrode **22** and the dummy n-side electrode **23**, the p-side electrode **21**, n-side electrode **22** and dummy n-side electrode **23** can be brought into contact with the Sn solder layers **34**, **36** and **37**, respectively, while holding the GaN semiconductor laser wafer and the photo-diode built-in Si wafer in parallel with each other. In this state, the GaN semiconductor laser wafer and the photo-diode built-in Si wafer are heated to approximately 300° C., for example, to melt and weld Sn solder layers **34**, **36** and **37** to the p-side electrode **21**, n-side electrode **22** and dummy n-side electrode **23**, respectively.

After that, the c-face sapphire substrate **11** is lapped from its bottom surface at least deep enough to reach the grooves **24**. That is, lapping is done to maintain only a slight thickness of the c-face sapphire substrate **11**. As a result, as shown in FIG. **13**, the structure holding GaN semiconductor lasers separated from each other on the Si substrate **31** is obtained.

Next, as shown in FIG. **14**, the Si substrate **1** is fully cut into discrete semiconductor lasers by dicing. As a result, LOP having a GaN semiconductor laser chip mounted on the Si substrate **31** with the built-in pin photo diode is obtained.

After that, as shown in FIG. **15**, LOP is mounted on a heat sink **42** of a predetermined package **41** via a Ag paste layer **43**, for example, orienting the side of the Si substrate **31** of LOP be in contact with the heat sink **42**. Thereafter, the Al pad electrode **35** on the Si substrate **31** is bonded to an electrode lead **44** with a wire **45**, and the Al pad electrode **40** (not shown in FIG. **14**) is bonded to an electrode lead **46** with a wire **47**. Then, a cap having a window (not shown) is applied to seal it.

After these steps, the intended GaN semiconductor laser is completed.

As explained above, according to the first embodiment, the GaN semiconductor laser wafer is prepared by a number of laser structures and electrodes on the AlGaInN semiconductor layer **20** on the c-face sapphire substrate and making grooves **24** deep enough to reach the c-face sapphire substrate **11** so as to separate individual semiconductor lasers whereas the photo-diode built-in Si wafer is prepared by previously making photo diodes and solder electrodes thereon; then the surface of the GaN semiconductor laser wafer where the AlGaInN semiconductor layer **20** appears is bonded to the surface of the photo-diode built-in Si wafer where the photo diodes appear; and these bonded GaN semiconductor laser wafer and photo-diode built-in Si wafer are divided by dicing into discrete laser chips. Therefore, a number of GaN semiconductor lasers can be manufactured simultaneously in a full batch process. Thus, the invention can remarkably improves the productivity of GaN semiconductor lasers, and can reduce the manufacturing cost significantly.

Next explained is a GaN semiconductor manufacturing method according to the second embodiment of the invention.

In the second embodiment, GaN semiconductor lasers can be separated by dicing the c-face sapphire substrate **11** from its bottom surface deep enough to reach the grooves **24** as shown by the dot-and-dash line in FIG. **12**, instead of lapping the c-face sapphire substrate from its bottom surface like the first embodiment. In the other respect, the second embodiment is the same as the first embodiment, and explanation there of is omitted.

The second embodiment also have the same advantages as those of the first embodiment.

Next explained is a GaN semiconductor laser manufacturing method according to the third embodiment of the invention.

In the third embodiment, instead of bonding the GaN semiconductor laser wafer to the photo-diode built-in Si wafer like the first embodiment, a GaN semiconductor laser bar **48** having a predetermined number of built-in laser structures is spread over the photo-diode built-in Si wafer as shown in FIG. **16**, and they are bonded in the same manner as the first embodiment. In the other respect, the third embodiment is the same as the first embodiment, and explanation thereof is omitted.

The third embodiment also ensures the same advantages as those of the first embodiment.

Next explained is a GaN semiconductor laser manufacturing method according to the fourth embodiment of the invention.

In the fourth embodiment, as shown in FIG. **17**, projections equal in height to the level of the contact surface of the p-side electrode **21** are made at opposite ends of the AlGaInN semiconductor layer **20** of the GaN semiconductor laser wafer in the direction normal to the cavity lengthwise direction. The projections prevent the solder of the Sn solder layers **36**, **38** from flowing out when the GaN semiconductor laser wafer is bonded to the photo-diode built-in Si wafer and the Sn solder layers **34**, **36** and **38** are melted and welded.

The fourth embodiment also ensures the same advantages as those of the first embodiment.

Next explained is a GaN semiconductor laser manufacturing method according to the fifth embodiment of the invention.

In the fifth embodiment, as shown in FIG. **18**, an Al electrode **49**, Al pad electrode **35** and dummy Al electrode **37** are formed on the SiO_2 film **32** made on the Si substrate **31**. The Al electrode **49** is in ohmic contact with an n^+-type layer formed on the surface of the Si substrate **31** via a contact hole, not shown, and the Sn solder layer **34** is made on the Al electrode **49**. The Sn solder layer **36** is formed on the Al pad electrode **35** via a Ti/Ag film **50**. Similarly, the Sn solder layer **38** is formed on the dummy Al electrode **37** via the Ti/Ag film **50**. In this case, thickness of the Ti/Ag film **50**, i.e., the difference in height of the Sn solder layers **36** and **38** from the Sn solder layer **34**, is equal to the different in height of the p-side electrode **21** from the n-side electrode **22** and the dummy n-side electrode **23** on the GaN semiconductor laser wafer. In the other respect, the fifth embodiment is the same as the first embodiment, and explanation thereof is omitted.

The fifth embodiment also ensures the same advantages as those of the first embodiment.

Next explained is a GaN semiconductor laser manufacturing method according to the sixth embodiment of the invention.

In the sixth embodiment, as shown in FIG. **19**, the SiO_2 film **32** made on the Si substrate **31** has formed openings **32a**. In the portion of each opening **32a**, a semi-spherical Sn solder layer **34** is formed via an Al electrode **49** and a Ti/Ag

film 50. On one side of each opening 32*a*, a semi-spherical Sn solder layer 36 is formed on the SiO_2 film 34 via the Al pad electrode 35 and the Ti/Ag film 50. On the other side of each opening 32*a*, a semi-spherical Sn solder layer 38 is formed on the SiO_2 film 32 via the dummy Al electrode 37 and the Ti/Ag film 50. In this case, areas of the Ti/Ag film 50 on the Al pad electrode 35 and the dummy Al electrode 37 are sufficiently larger than the area of the Ti/Ag film 50 on the Al electrode 49. Responsively, diameters, i.e. heights, of the semi-spherical Sn solder layers 36, 38 formed on the Al pad electrode 35 and the dummy Al electrode 37 via the Ti/Ag film 50 are sufficiently larger than the diameter, i.e. height, of the semi-spherical Sn solder layer 34 formed on the Al electrode 49 via the Ti/Ag film 50. More specifically, the difference in height of the semi-spherical Sn solder layers 36, 38 from the semi-spherical Sn solder layer 34 is equal to the difference in height of the p-side electrode 21 from the n-side electrode 22 and the dummy n-side electrode on the GaN semiconductor laser wafer. These semi-spherical Sn solder layers 34, 36, 38 can be made by first making Sn layers equal in thickness on full areas of respective portions of the Ti/Ag film 50, and then heating the Si substrate 31 to approximately 300° C. to melt the Sn layers. In the other respect, the sixth embodiment also ensures the same advantages as those of the first embodiment.

Having described specific preferred embodiments of the present invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or the spirit of the invention as defined in the appended claims.

For example, numerical values, structures, substrates, soldering materials and processes presented in the first, second and third embodiments are not but examples, and any other appropriate numerical values, structures, substrates, processes, and so on, may be used.

The first embodiment has been explained as making the n-side dummy electrode 23 on the AlGaInN semiconductor layer 20 of the GaN semiconductor laser wafer. However, the n-side dummy electrode 23 may be omitted, if appropriate. In this case, the dummy Al electrode 37 and the Sn solder layer 38 need not be made on the photo-diode built-in Si wafer.

The fourth embodiment has been explained as making projections at opposite ends of the AlGaInN semiconductor layer 20 in the direction normal to the cavity lengthwise direction. However, the projections may be made slightly in-side of these opposite ends.

The sixth embodiment has been explained as previously making the semi-spherical Sn solder layers 34, 36, 38 on the photo-diode built-in Si wafer before it is bonded. However, the semi-spherical Sn solder layers 34, 36 and 38 may be made by forming flat Sn solder layers on respective portions of the Ti/Ag film 50 with the same configurations there with and all with the same thickness, then stacking the photo-diode built-in Si wafer on the GaN semiconductor laser wafer, and thereafter heating them to 300° C.

Although the first to sixth embodiments have been explained as applying the invention to fabrication of GaN semiconductor lasers, the invention is also applicable to fabrication of GaN light emitting diodes or GaN electron transport devices like GaN FET.

As described above, the semiconductor device manufacturing method according to the invention enables simultaneously manufacturing a large number of devices in a full batch process, by bonding the first substrate, previously having formed a plurality of devices made of nitride compound semiconductor layers, to the second substrate, and dividing these bonded first and second substrates. Therefore, semiconductor lasers, light emitting diodes or electron transport devices using nitride III-V compound semiconductors can be manufactured with a high productivity.

Furthermore, in the semiconductor device according to the invention, projections on the surface of the nitride III-V compound semiconductor layer is effectively used to prevent the solder from flowing out laterally while the solder is welded onto taller one of the p-side electrode and the n-side electrode.

What is claimed is:

1. A method for manufacturing a semiconductor device comprising the steps of:

bonding a surface of a nitride III-V compound semiconductor layer of a first wafer-shaped or bar-shaped substrate to one of major surfaces of a second wafer-shaped or bar-shaped substrate, said first substrate having said nitride III-V compound semiconductor layer on one of major surfaces thereof to form a plurality of devices;

forming said plurality of devices on said nitride III-V compound semiconductor layer; and

dividing said first substrate and said second substrate bonded together into a plurality of portions.

2. The method for manufacturing a semiconductor device according to claim 1 wherein said first substrate and said second substrate bonded together are divided into individual devices.

3. The method for manufacturing a semiconductor device according to claim 1 wherein said plurality of devices are separated by grooves deep enough to reach said first substrate.

4. The method for manufacturing a semiconductor device according to claim 1 further comprising the step of lapping said first substrate from the other major surface thereof at least deep enough to reach said grooves.

5. The method for manufacturing a semiconductor device according to claim 4 further comprising the step of dicing said first substrate from the other major surface thereof at least deep enough to reach said grooves.

6. The method for manufacturing a semiconductor device according to claim 1 wherein electrodes of said devices are formed on said nitride III-V compound semiconductor layer of said first substrate, and solder electrodes are formed on said one major surface of said second substrate in locations corresponding to said electrodes of said devices.

7. The method for manufacturing a semiconductor device according to claim 6 wherein said first substrate and said second substrate are bonded together by bonding said electrodes of said devices on said first substrate to said electrodes on said second substrate.

8. The method for manufacturing a semiconductor device according to claim 1 wherein said devices are semiconductor lasers, light emitting diodes or electron transport devices.

9. The method for manufacturing a semiconductor device according to claim 1 wherein said first substrate is a sapphire substrate, SiC substrate, Si substrate, spinel substrate or ZnO substrate.

10. The method for manufacturing a semiconductor device according to claim 1 wherein said second substrate is a Si substrate, SiC substrate, diamond substrate, AlN substrate, GaN substrate, ZnO substrate or spinel substrate.

11. The method for manufacturing a semiconductor device according to claim 1 wherein said devices are semi-

conductor lasers, and said second substrate is a Si substrate on which photo diodes for monitoring light outputs of said semiconductor lasers are formed for respective devices.

12. A method for manufacturing a semiconductor device comprising the steps of:

bonding a surface of a nitride III-V compound semiconductor layer of a first wafer-shaped or bar-shaped substrate to one of major surfaces of a second wafer-shaped or bar-shaped substrate, said first substrate having said nitride III-V compound semiconductor layer on one of major surfaces thereof to form a plurality of devices separated from each other by grooves deep enough to reach said first substrate, said nitride III-V compound semiconductor layer having on a surface thereof first projections and second projections extending in parallel with said grooves and separated from each other; and

dividing said first substrate and said second substrate bonded together into a plurality of portions.

13. A method for manufacturing a semiconductor device comprising the steps of:

bonding a surface of a nitride III-V compound semiconductor layer of a first wafer-shaped or bar-shaped substrate to one of major surfaces of a second wafer-shaped or bar-shaped substrate, said first substrate having said nitride III-V compound semiconductor layer on one of major surfaces thereof to form a device; and

dividing said first substrate and said second substrate bonded together into a plurality of portions.

14. A method for manufacturing a semiconductor device comprising the steps of:

preparing a GaN semiconductor laser wafer by:

forming a plurality of semiconductor lasers on an AlGaInN semiconductor layer formed on a top surface of a c-face sapphire substrate, said plurality of semiconductors being separated from each other by grooves formed deep enough into said AlGaInN semiconductor layer to reach said c-face sapphire substrate;

forming a p-side electrode and an n-side electrode in each of said semiconductor lasers;

bonding said GaN semiconductor laser wafer to a photo-diode built-in Si wafer having formed thereon at least a pellet corresponding to each semiconductor laser, each pellet having a photo-diode for monitoring light outputs and at least two solder electrode, by positioning said p-side electrode and said n-side electrode in alignment with said at least two solder electrodes, respectively;

separating from each other said semiconductor lasers on said photo-diode built-in Si wafer by removing said c-face sapphire substrate from a bottom surface deep enough to reach said grooves;

dividing said photo-diode built-in Si wafer by dicing into discrete pellets; and

assembling a resulting GaN semiconductor laser chip on a package.

15. The method for manufacturing a semiconductor device as claimed in claim **14**, wherein said c-face sapphire substrate is removed from said bottom surface by lapping said c-face sapphire substrate from said bottom surface.

16. The method for manufacturing a semiconductor device as claimed in claim **14**, wherein said c-face sapphire substrate is removed from said bottom surface by dicing said c-face sapphire substrate from said bottom surface.

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